THE SECULAR VARIATION IN THE GEOMAGNETIC FIELD AND OTHER GEOPHYSICAL PHENOMENA

With 7 figures

by

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SUMMARY

The author makes a comparison between the pulsation recognizable in the secular variation of the geomagnetic field of about a 50 years period and similar periods observable in the speed of the Eart's rotation, in the amplitude of the variation of the polar altitude, and in the variation of sea level. From the conformity of the periods he draws the conclusion, that the secular variation of the geomagnetic field is connected with a large-scale movement of masses in the interior of the Earth.

Supposed, that the eccentricity of about 350 – 400 km of the Earth's magnetic centre is running together with the Earth's inner core, then the eccentricity of the masses in that dimension produces with respect to direction and size the triaxiality of the Earth known from geodesy, i.e. the equatorial ellipticity. It is possible, that the secular variation of the geomagnetic field can be attributed to tidal forces acting on the inner core, and in consequence, to displacement of the core.

It is well known that the magnetic field of the Earth is slowly changing. Long series of observations have proved that the total period of a variation amounts to about 500 years. This period is long in the history of magnetic measurements, but very short as compared with the periods of geological ages. It is, therefore, a great problem whether a slow variation bound to the interior of the Earth, i. e. presumably one of geological character of the Earth, i. e. presumably one of geological character, could cause a significant process of such a short period.

The investigations are rendered difficult by the fact that each magnetic component is separately measured and maps are plotted on the basis of measuring points spread all over the surface of the Earth. This mode of representation is very artificial. In the case of secular variations it is not the individual components which change but the whole space vector; another extraordinary difficulty for our observations is the plane representation of

the globe. It is not surprising at all that with so many arbitrary elements nothing but a decomposed irregular image of the secular magnetic variation could be obtained.

Inspite of the difficulties mentioned above, it could be shown as a result of the mathematical analysis of these maps and of their direct comparison that a certain western tendency is observable in the process of variation.

From time to time the coefficients of the spherical functions of the geomagnetic field were computed from the magnetic world charts valid for different epochs. Even by making comparisons of the coefficients dating from different times, conclusions might be drawn to certain general characteristics of the secular variations, such as, for instance, that the seat of the secular variations is in the interior of the Earth, further, that the magnetic centre of the Earth is by 300 to 400 km eccentric in the direction of the western part of the Pacific Ocean. The point of eccentricity is wandering slowly towards West, in accordance with the secular variation.

For studying the details of secular variations, it is more advisable to make use of the magnetic data of certain observatories, these meet much better the requirements for uniformity and homogenity than the geometrical charts, or rather the coefficients of spherical functions computed from the same.

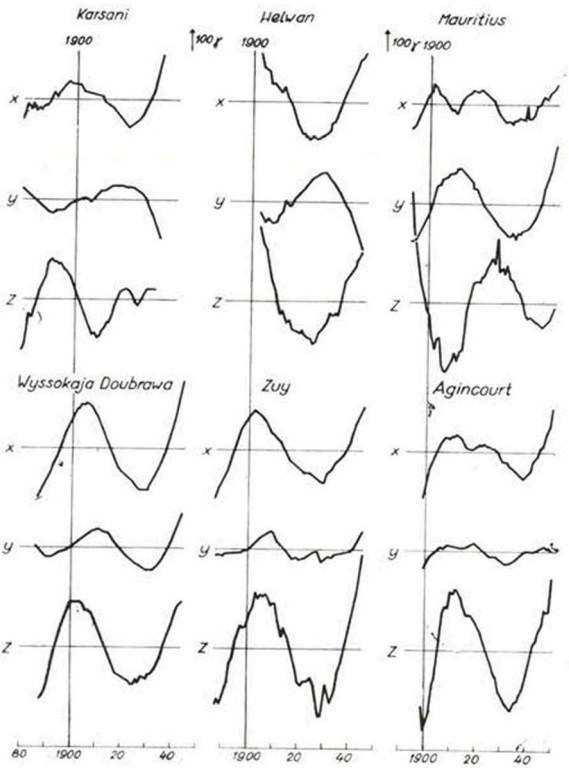

Fig. 1. The 50 years period of the secular variation of the earthmagnetic field.

By approximating the data of the observatories in the temperate zone with the power function of time in applying the method of least squares, one sees that over the mathematical curve, which may be considered as the average cours, is superposed a very considerable wave of 200 to 300 gamma amplitude and of about a 50 years period (Fig. 1.).

In order to avoid the arbitrariness implied in the separation of the individual coefficients, it is advisable to study this phenomenon in the system of co-ordinates given by the tangent, the normal and the binormal of the adjusted secular variation.

The projection of the superposed vector on the direction of the space curve tangent is — within certain periods — positive, then negative, i.e. the measured point as compared with the adjusted one is from time to time fast, respectively late. This phenomenon is a result of the acceleration, respectively retardation of the secular variation, i.e. it corresponds with a longitudinal wave. In the observatories of the Northern hemisphere this accelaretion and retardation appears at the same time and the longitudinal wave of secular variation has its minimum around 1910 and its maximum around 1935 [4] (Fig. 2.).

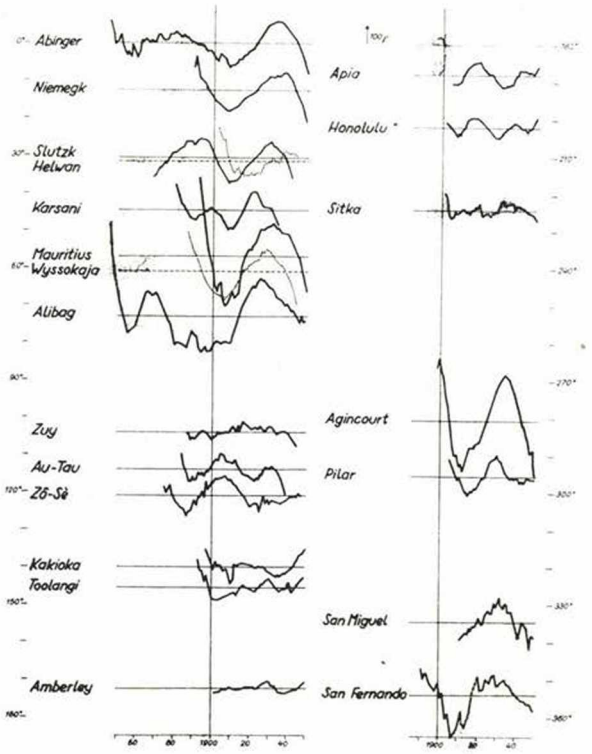

Fig. 2. **The longitudinal wave of the secular variation of the earthmagnetic field.**

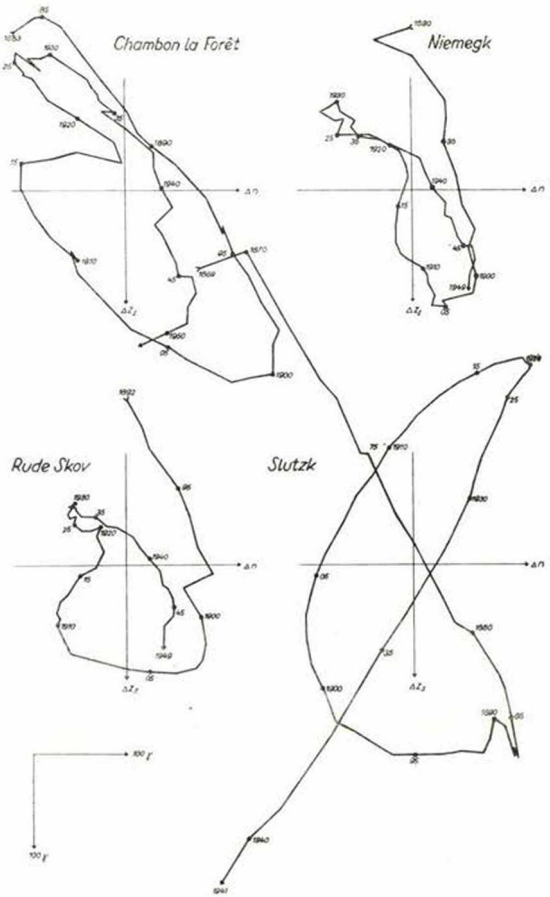

Fig. 3. The transversal effect of the secular variation of the earthmagnetic field.

The coefficients falling into the direction of the binormal and the main normal are representing the spiral-like movement of the end-point of the vector. This phenomenon may be called the transversal effect of the secular variation. The direction of turning of the wave vector is clockwise in the northern temperate zone [4] (Fig. 3.).

If one part of the process of secular variation is uniformly appearing nearly all over the Earth, then the main variation itself will be even more generally. The coordinate system X, Y, Z used to determi ne the magnetic vector is varying from point to point at the surface of the globe, it is, therefore, not suitable for recognizing the more general character of secular variation. In our further investigations the adjusted variation vectors may, as a consequence, be projected orthogonically onto the three coordinate planes perpendicular to each other and passing the centre of the Earth. If the centre of projection is lying around Pakistan, the picture of variation shows remarkable symmetry, since the variation vectors are turning against one another around

the centre of the projected picture, whilst the vectors at the observatories at the border are showing radially outwards (Fig. 4.). From this fact and from suitable side views it may be concluded that a circular current of a radius of about 3000 km is flowing around Pakistan as a centre in a depth of about 3000 km. The situation and the intensity of this circular current is varying in time and this could possibly be the cause of the general part of secular variation [3].

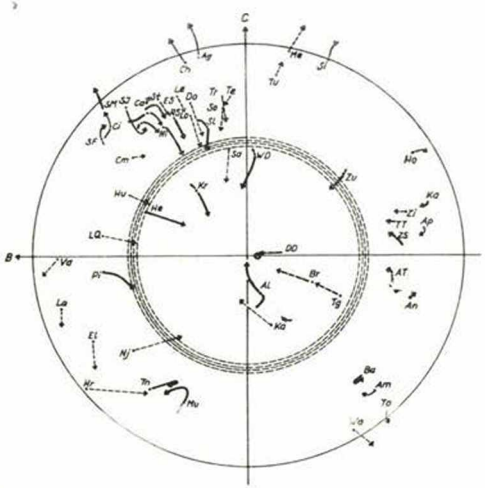

Fig. 4. The orthogonal projection of the adjusted vector diagrams of the secular variations as seen from Pakistan.

:::: means the assumed circuit; *o* is the magnetic centre of the Earth. (The courses at the observatories lying at the side of the viewpoint are represented by thick solid lines, those on the opposite side by thin solid lines, and the courses extrapolated from the shorter courses at the observatories for a 50 years long period are represented by broken lines.)

It is noteworthy that the magnetic centre of the Earth is perpendicularly eccentric to the direction showing from the geometric centre towards Pakistan, and is moving directly towards Pakistan. Supposed the internal core of the Earth is the holder of the terrestrial magnetism, this means that the Earth's core is moving towards this direction. Consequently, the magnetic field of the Earth has three essential directions: the magnetic axis, the direction connecting the geometrical centre with the magnetic centre and the direction of movement of the magnetic centre. The three directions are about perpendicular to each other.

As a consequence of the aforesaid fact, it is quite natural that – if a fifty years period is observable in the secular variation of the geomagnetic field – this variation should appear in the movement of the internal core of the Earth as well. And this phenomenon should manifest itself at the surface of the Earth in other phenomena too.

The definite 50 years period of certain phenomena is indicating, as a matter of fact, a remarkable shift of masses in the interior of the Earth. A periodical fluctuation of about 50 years is observable in the speed of rotation of the Earth

during the last fifty years. Around 1910, the Earth was late, and around 1935 she was fast as compared with the uniformly rotating Earth [11]. The amplitude of retardation and acceleration is $\pm 0{,}9$ sec. During a period like this, such a variation would be caused by the sinking or the rise of the sea level. Mass shifts of this size are not observed at the surface of the Earth and cannot be supposed neither in the crust nor in the outer mantle. The effective cause, accordingly, ought to be in the Earth's core (Fig. 5.).

A large-sized movement of masses is indicated, moreover, by the fact that a period of about fifty years is easily observed in the amplitude of the polar distance variation, which had its maximum around 1910 and 1958, and its minimum around 1935 (Fig. 5.) [10].

If the displacement of the magnetic centre is related to the large-sized mass movements in the interior of the Earth, this variation has to appear in the secular variation of the gravity field as well. We do not dispose of gravi-

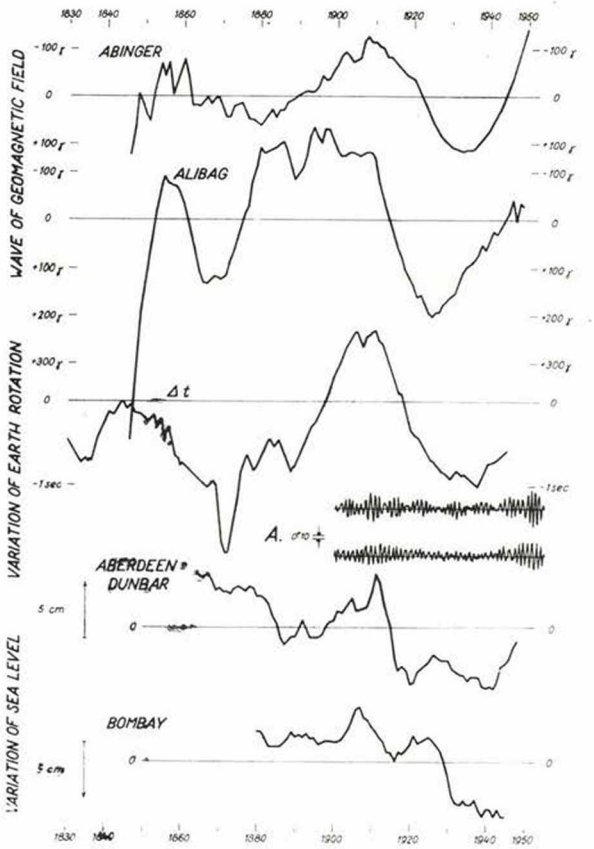

Fig. 5. The secular variations of various geophysical phenomena.
A. The variation of the amplitude of the oscillation of the polar heigth, and the same after the elimination of the shorter periods [10].

tational observational series of sufficient length and accuracy, but our long since observed sea-level height data correspond, after all, with the measurements of the height of the equipotential surface of the gravity field. It may be observed a certain connection between the long series sea-level observational data and the periodicity of previous phenomena (Fig. 5.) [5].

When comparing long series sea-level data systems submitted to overlapping averaging even the sea-level fluctuations show a certain general character. Thus the level surface variation in Sydney and Aberdeen, for instance, – which may be considered as opposite points of the globe – shows a definitely parallel course. The level surface height of Bombay and Tunis situated between them, as well as of Honolulu, lying in a far distance too, is showing, on the contrary, a definite counter-course. These features are justifying the allover character of the level surface variation. There is recognizable a periodicity of about fifty years in these data systems too (Fig. 6.).

The eccentric position and movement of the magnetic centre of the Earth are playing an important part in the above observations. Hence a possibly accurate knowledge of this very significant group of phenomena is required. Eccentricity is manifested, among others, by the fact that the horizontal intensity in the surroundings of the Western Pacific is by 10 000 gamma greater than in the Atlantic area situated at the opposite side of the Earth. Both the

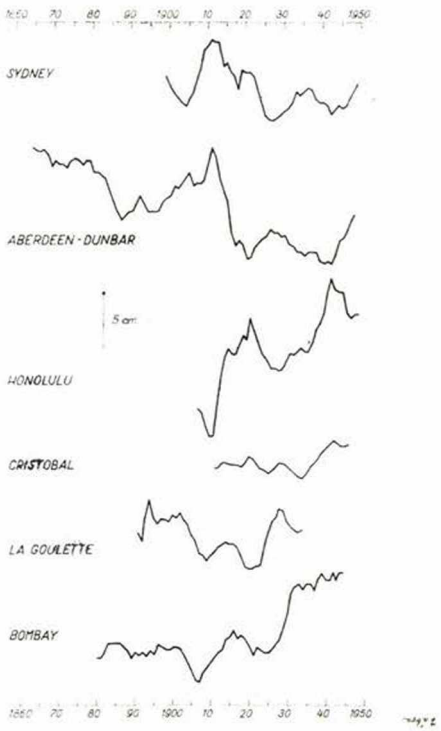

Fig. 6. The secular variation of the sea level at differents points of the Earth.

other magnetic components are similarly clear proofs of eccentricity. It is clear, accordingly, that the distortion of the geomagnetic field related to the eccentricity of the centre is by some orders of magnitude greater than the measuring accuracy of today.

By comparing the data of different epochs we can see that the magnetic centre is performing certain regular movements. It moved since Gauss in the W-NW direction with a speed of about 0,2° a year, whereas its eccentric position has moved between 300 and 400 km [6].

Magnetic eccentricity varied in the course of times, it is true, but it could always be followed continuously. Its demonstration is therefore based not on one single data system, but on numerous ones. We may consequently declare that the eccentricity of the geomagnetic field is an undeniable physical fact based on a great number of measuring data. Should this be true, a similar eccentricity must also be found in the internal material structure of the Earth.

It follows from the temporal displacement of the magnetic centre that it cannot be directly connected with the a continental structure of the Earth, not even with the structure of the crust and mantle. The change in time of these latters is not so essential [that an immediate periodic variation night be logically connected to them] similar to the magnetic secular variation. The origin of this effect can only be found under the crust and mantle, i.e., in the core. And from the long periodic character of the variation a process of great inertia may be concluded. We could presume therefore, that it concerns the eccentricity and slow shift of huge masses lying in great depths, as compared to the surface.

Now quite obviously the problem is raised that such an enormous eccentricity of huge gravitating masses may cause the static deformation of the globe. The direction of eccentricity of the magnetic field corresponds, as a matter of fact, with the direction of the equatorial great axis of the triaxial Earth

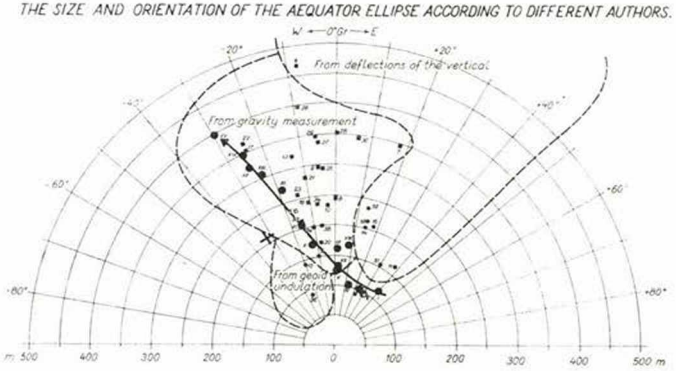

Fig. 7. The difference of the major and minor axis of the equatorial ellipse and the direction of its major axis calculated on the basis of gravity data (small circles and square points), orbits of artificial satellites (cross), and magnetic eccentricity (wide cirles). The solid arrow indicates the variation of the equatorial ellipse, calculated from magnetic data between 1550 and 1955 (2, 8, 12).

within the limits of measuring accuracy. Supposed that the solid state internal core of a radius of 1250 km and of a density of 17 g/cm³ is lying excentrically in the substance of the external core of liquid state and of a density of 11 g/cm³, the equipotential surface deformation at the surface of the Earth indicates the equatorial oblateness obtained from different geodetic measurements and observations of artificial satellites are not only according to its direction, but also according to its magnitude (Fig. 7.) [2].

Material eccentricity has, of course, considerable consequences and, by emphasizing it, many phenomena can easily be explained. The eccentrical terrestrial core is, as a matter of fact, unbalanced within the solar system, Sun and Moon having a gravitational influence similar to the tide-producing force. As a consequence of the attractive force, the internal core eccentrically floating in the fluid external core is moving from east to west just as the tide-wave does. The western tendency of secular magnetic variation has thus become quite natural. The problem of the origin of the energy necessary to maintain the secular variation has been cleared as well. As long as the Earth's core is floating eccentrically in the fluid external core and around us enormous celestial bodies are moving, this eccentrical core is necessarily moving in the western direction. The energy required to maintain this movement has its origin from the energy of movement of the Earth, the Sun and the Moon.

The assumption of the eccentricity of the Earth's core requires, of course, the explanation of the eccentricity as well. The Earth's core is obviously developing round the point of maximum pressure. The point of maximum pressure, on the other hand, in case of an inhomogeneous Earth does not coincide with the geometrical centre of the Earth. If the Earth's substance on the oceanic hemisphere -- i.e. around the area of the Pacific Ocean — is more dense than on the continental one, the point of maximum pressure is shifting from the centre towards the Pacific, and thus the eccentricity is established.

There are even some geological comsequences of this idea. At the boundary surface of the two media of different densities has developed the volcanic zone of high seismicity around the Pacific. The rotating energy contents of the denser hemisphere are greater than those of the thinner one and when the speed of rotation of the Earth is reducing, the material falls forwards, piles up the substance ahead and is breaking off from that behind. This phenomenon can be seen in the foldings of the Cordilleras and Andes as well as in the formation of Eastern Asian-Australian deep-sea trenches. There are deep-sea trenches along the western shores of America too, it is true, but they are insignificant in their depth and width as compared with those of the Western Pacific, and their formation is in all probability rather due to piling than to rupturing phenomena.

When assuming the eccentricity and movement of the Earth's core it should be studied whether the consequences hereof would not render impossible such an hypothesis.

The movement of the Earth's core is accompanied by the alteration of the form and the gravity field of the Earth. According to our computations (carried out by Miss Anna Pintér in 1962), these variations reach in the height of the equipotential surface the order of one meter a year and in the intensity of the gravity field the order of a tenth milligal per annum.

It is well-known that after having repeated the Kühne-Furtwängler measurement carried out at the beginning of this centruy, a difference of 10 to 15 milligal has been observed. Certain objections were raised against this measurement, it is true, the first measurement, consequently, cannot be considered as a solid infallible starting basis, nevertheless it ought to be mentioned that in the last fifty years the intensity of the gravity in Potsdam has – as a consequence of the movement of the Earth's core – decreased by 11 mgal, this value gives the observed difference with the correct sign.

It is remarkable that the results of the absolute gravity measurements repeated after decades are differring from each other beyond the probable error of measurements. When comparing Potsdam with several other absolute base points, various differences are obtained as well. On the other hand there have been relative gravity profiles measured along rather long lines and repeated after ten years where no measurable variation has been indicated. In order to solve this problem we have obviously to carry out for a long period a great number of highly accurate relative and absolute gravity measurements. The possibility of the secular variation of the gravity field should, however, theoretically never be precluded.

Long ago it has been observed that the geographical coordinates of the astronomical or geodetic points are varying in time. As an explanation of this phenomenon it was used to presume that the position of the points at the Earth's surface is varying in time. When assuming the movement of the Earth's core, this problem is seen under quite another light. In consequence of the core movement the direction of the gravity field is varying too. This change of direction plays a part as well in the locations performed in different periods.

When computing the changes of directions occurring in consequence of the shift of the Earth's core we found that in extreme cases they can reach 0,08'' a year (E. Aczél, 1962.). The places of greatest variations are always the seas, whilst on continental cultured areas the variation amounts only to 0,02'' a year. About these $\Delta\lambda$ and $\Delta\varphi$ speeds of variation are shown by the results of our highly accurate locating measurements performed in the last decades. This computation did not thus lead to an insolvable contradiction.

From the coincidence of the periods of certain phenomena and from other natural phenomena we may conclude that our Earth is not a homogeneously balanced formation and its departure from it is manifested by the phenomena of considerable secular variations and movements. The study of these very phenomena permits a more detailed knowledge of the internal structure and features of the Earth. Therefore it is one of the most important works for the geophysicist dealing with the Earth as a whole to determine, how far the conditions of the homogeneity and equilibrium could be valid and when ought to be already used the inhomogeneous Earth's model satisfying the demands of the accuracy in higher degree.

As to our future aims, we intend to disclose the energy conditions of the group of phenomena and to investigate the natural phenomena which may give further informations on the degree of inhomogeneity of our Earth. A certain inhomogeneity is existing without any doubt, since a complete homogeneity in

substance and energy would preclude any movement and accumulation of tension, whereas our experiences with the Earth are strictly contradictory.

The investigation of the relationships may bring results in many scientific branches and, following this way, we could perhaps better approach to an explanation of the physical background of phenomena. Unfortunately, the consequent pursuance of the theorem of inhomogeneity requires to abandon the concentric structure of our Earth, and the consequence of which is a sudden increase of the mathematical difficulties.

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